Hierarchical Micro/Nano Reinforced Multiscale Hybrid Composites for Vehicle Applications

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Project ID: mat258

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Overview

Timeline

- Project start: Jun 28, 2021
- Project end: Mar 27, 2022
- Percent complete: 100%

Budget

- Total project funding
  - DOE share: $199,218
  - Contractor share: $0
- Funding for FY 2021: $100,593
- Funding for FY 2022: $98,625

Barriers and Technical Targets

- Fracture and energy absorption characteristics of lightweight polymer composites are inadequate
- Need low-cost precursors and energy-efficient manufacturing of fibers for composites
- Need new kinds of micro- and nano-fillers to enable multiscale reinforcing in polymer composites

Partners

- Interactions/Collaborations
  - Georgia Southern University (GSU)
- Project Lead
  - Advent Innovations Limited Company

Relevance

Objectives

The overarching goal is to develop lightweight multiscale hybrid nanocomposite fibers (HyFi) to reduce weight, volume, and costs of automotive structural components, and to increase vehicle energy efficiency. The specific Phase I objectives included:

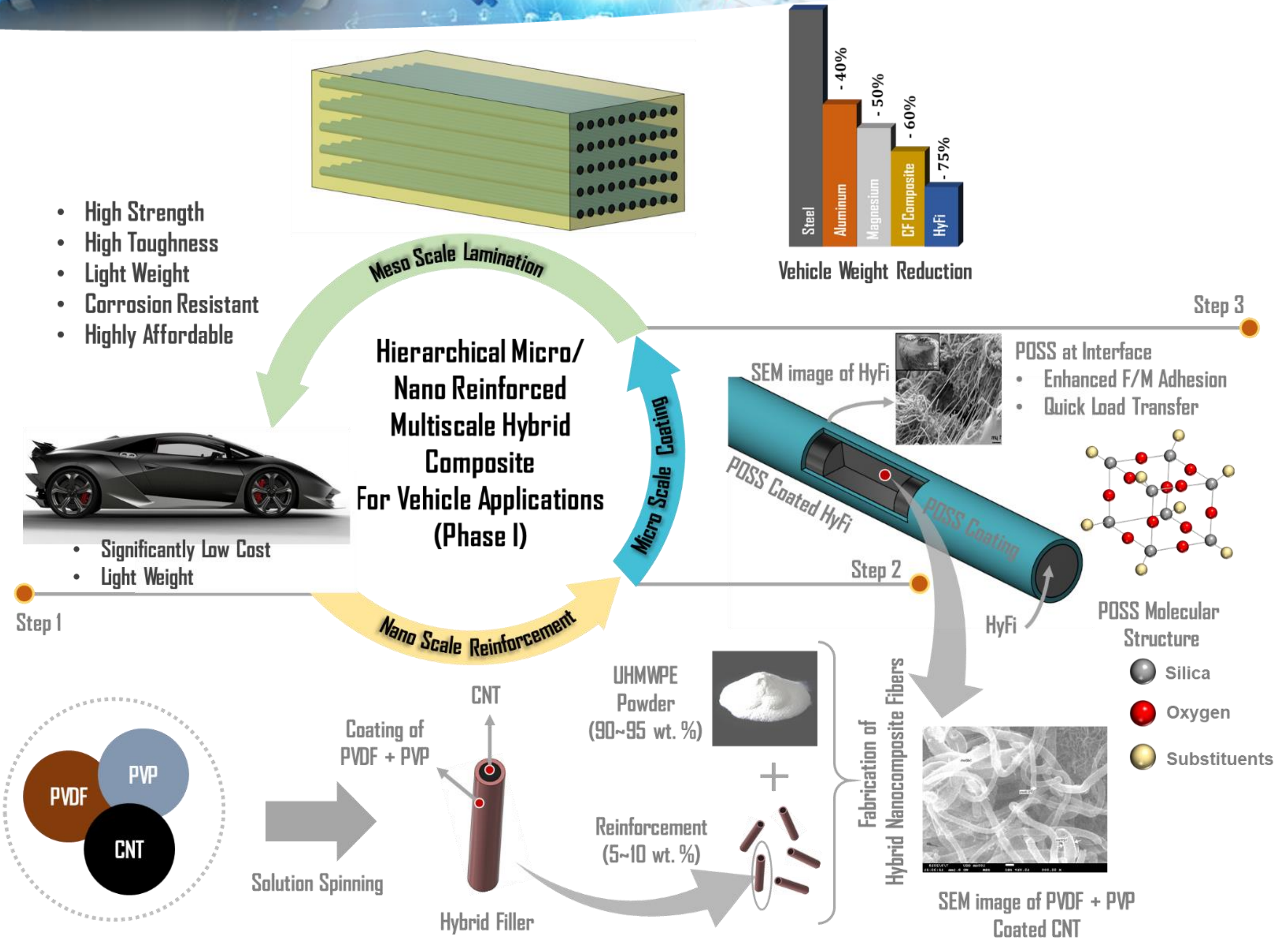
- Synthesize and process HyFi fibers with multiscale reinforcements
- Use novel HyFi fibers to manufacture composite coupon specimens
- Conduct mechanical testing to determine material properties

Impacts

- Multiscale fiber provides mutually exclusive properties: high specific strength and high specific toughness
- Increased vehicle energy efficiency, increased crashworthiness capabilities, and reduced noise, vibration, and harshness (NVH)
- HyFi fiber constituents enable self-sensing and self-diagnostic capabilities for structural health monitoring
- 50% lower cost and energy consumption to manufacture, and 70% smaller carbon footprint than carbon fibers

Approach

- Synthesize ultrahigh molecular weight polyethylene (UHMWPE) powder and carbon nanotubes (CNTs) that are coated with polyvinylidene fluoride (PVDF) and polyvinylpyrrolidone (PVP). This increases the fiber's strength- and toughness-to-weight ratios.
- Strain harden fibers to make them stronger and stiffer through plastic deformation and CNT alignment.
- Coat fibers with Polyhedral Oligomeric Silsesquioxanes (POSS) to increase fiber/matrix bonding and enhance filler/matrix interfacial load transfer.
- Fabricate composite specimens using POSS-coated HyFi fibers in thermoset epoxy-based matrix using vacuum-assisted resin transfer molding (VARTM) process.
- Conduct mechanical testing of the manufactured composite specimens to demonstrate the feasibility of multiscale (both micro- and nanoscale) reinforcements in polymer composites.



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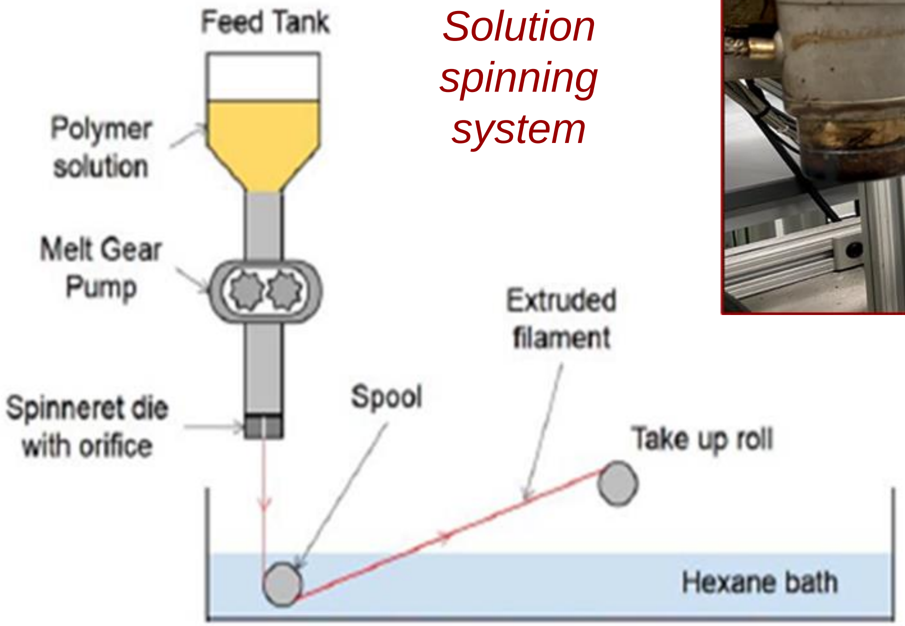
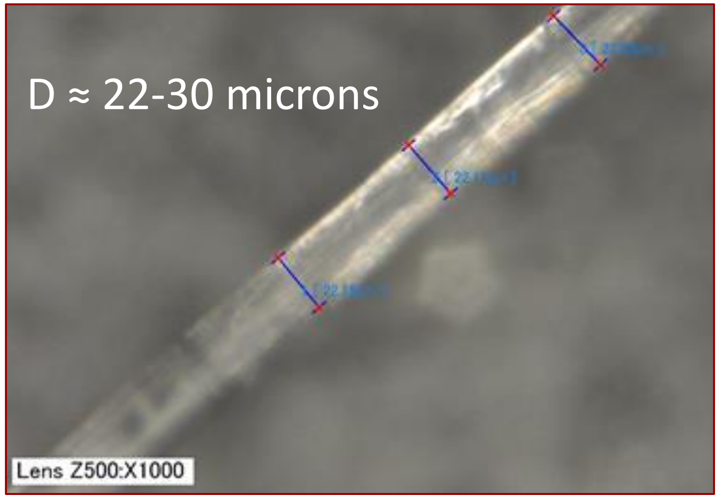
Technical Accomplishments and Progress

Synthesis and Processing of HyFi Fibers



Solution spinning system



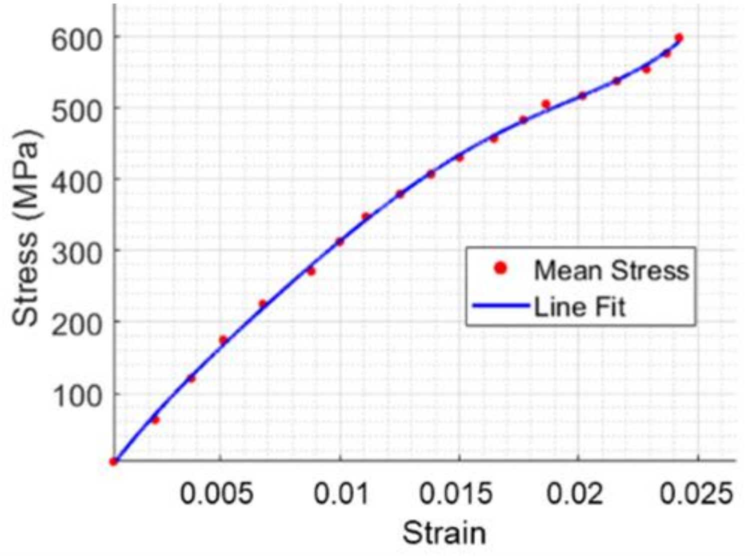
- GSU synthesized and processed ~15 grams of HyFi fibers
- After strain hardening and POSS coating, fibers were ~30 microns in diameter
- Fiber strength was measured to be 4 GPa with maximum strain of 1300%

This is the first year that the project has been reviewed

Technical Accomplishments and Progress

Composite Specimen Manufacturing and Testing

VARTM process



- Both long-fiber unidirectional fiber and chopped short-fiber composite specimens were manufactured and tested.
- Specimens were made with various fiber-resin ratios and architectures, including all carbon fiber, all HyFi fiber, and hybrid carbon-HyFi fibers.
- HyFi specimens exhibited high toughness and energy absorption properties.

Collaboration and Coordination with Other Institutions

- **Georgia Southern University** *(Phase I and Phase II)*
  - Synthesis of HyFi precursor materials. Streamlining fiber production by automating and optimizing strain hardening, electrospraying of POSS, and treatments to induce piezoelectric properties of the HyFi fibers.

- **Ford Motor Corporation** *(Phase II and beyond)*
  - Provide in-kind support to Advent through testing of composite samples to benchmark performance against competing materials technologies. Ford will also provide feedback on manufacturability, cost and potential applications. Throughout the project, Ford will be providing guidance to the research team, support through technical discussions and advice on end use viability.

- **JTEKT North America Corporation** *(Phase II and beyond)*
  - Provide in-kind support to Advent in terms of testing the HyFi composite coupons/components for impact based on industry standards used for qualifying parts at JTEKT.

- **Steelhead Composites** *(Phase II and beyond)*
  - Provide in-kind support to test the technology on high-pressure vessels/tanks applications and also in other composite structures that require embedded sensing technology.

Proposed Future Research

- Scale-up and streamline HyFi fiber production, including automating strain hardening and electrospraying of POSS.
- Apply treatments to induce piezoelectric properties.
- Develop fiber packaging methods, such as prepreg, fabric, tows/yarns, etc.
- Standardize VARTM process for both long and short HyFi fibers.
- Establish self-sensing and self-diagnostic capabilities of HyFi material.
- Component testing with industrial partners (Ford and JTEKT Corporation).
- Quantify fiber manufacturing costs in terms of dollars, carbon emissions, and energy use.

Any proposed future work is subject to change based on funding levels.

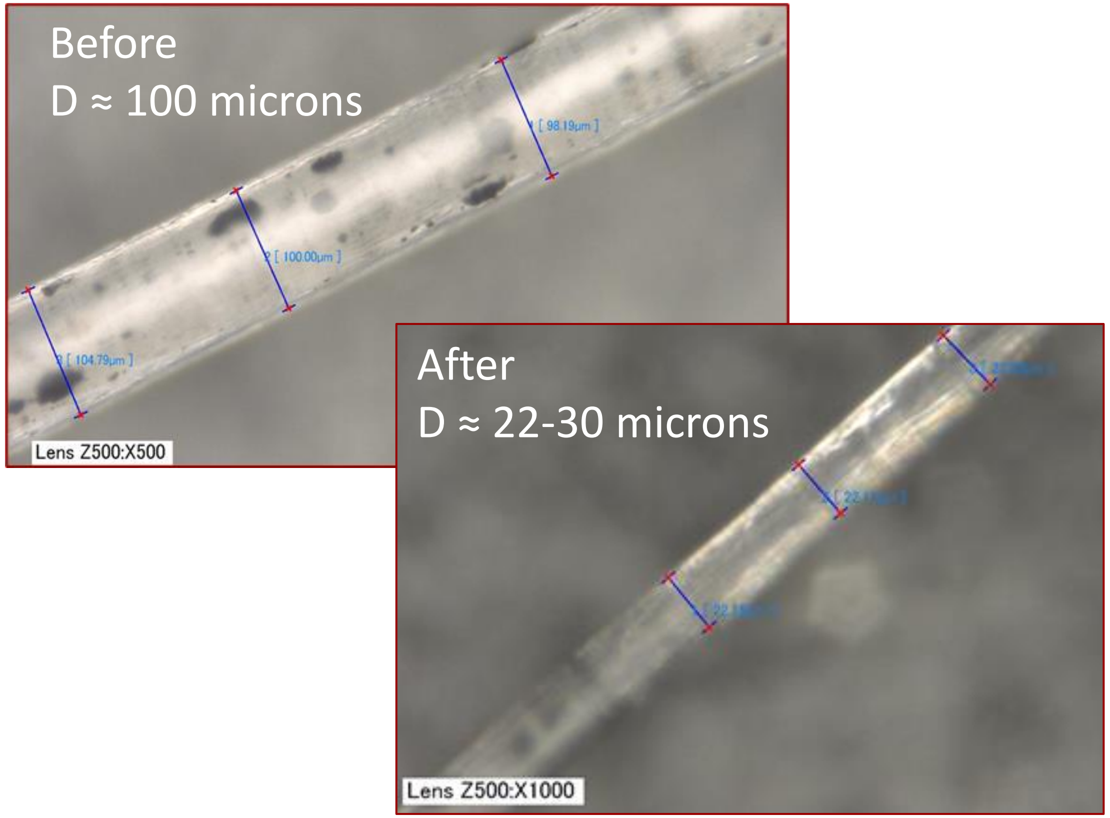
Summary

- Advent and GSU are developing lightweight multiscale hybrid nanocomposite fibers (HyFi) to reduce weight, volume, and costs of automotive structural components, and to increase vehicle energy efficiency.
- The HyFi fibers exhibit high strength-to-weight and toughness-to-weight ratios, and the ability to absorb and redistribute impact energy before local failure conditions are met.
- The HyFi fibers are coated with POSS to increase fiber/matrix bonding and enhance filler/matrix interfacial load transfer.
- Both long-fiber and short-fiber (chopped) composite specimens were manufactured and subjected to mechanical testing to demonstrate the enhanced properties.
- The energy absorbing nature of the material will not only increase crashworthiness and reduce impact intrusion, but it will also reduce noise, vibration, and harshness (NVH).

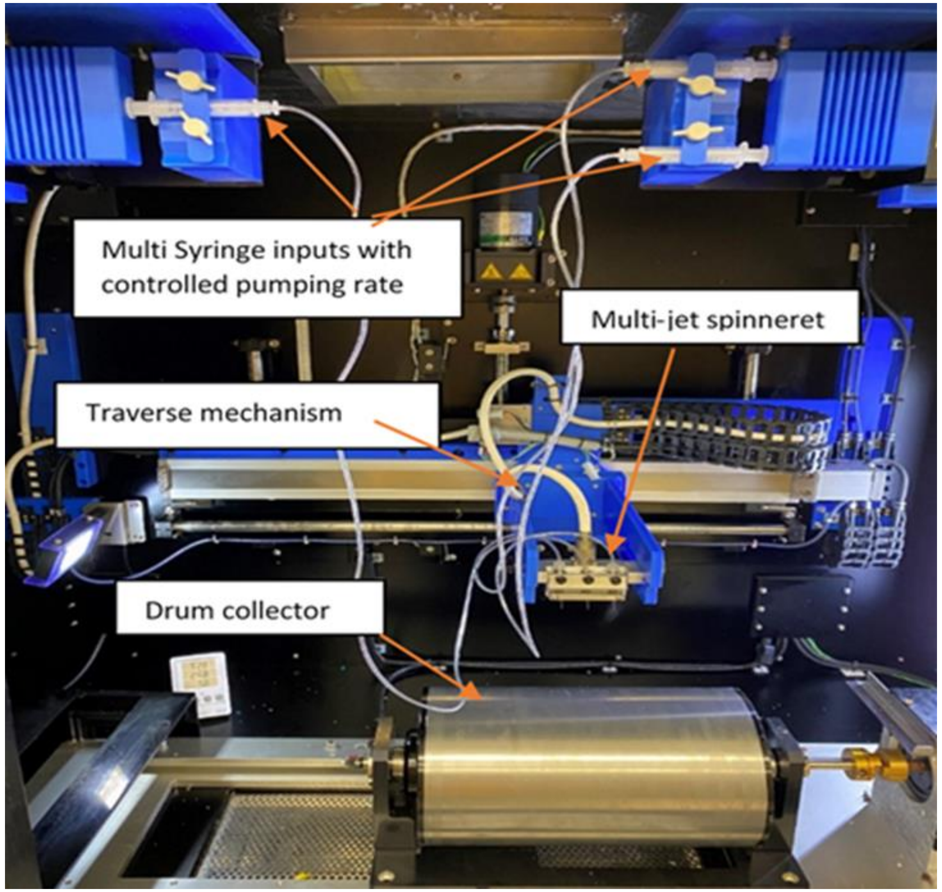
Technical Backup Slides

Synthesis and Processing of HyFi Fibers

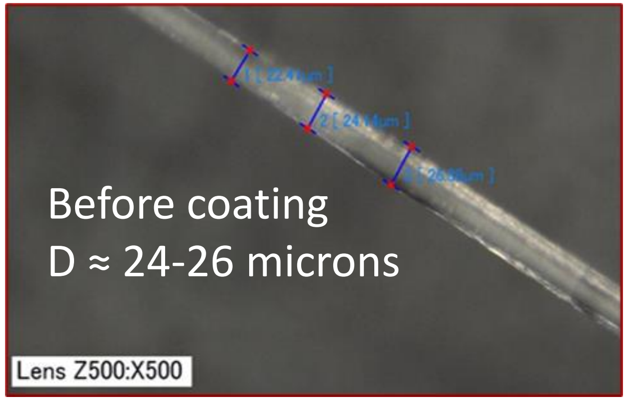
Strain Hardening

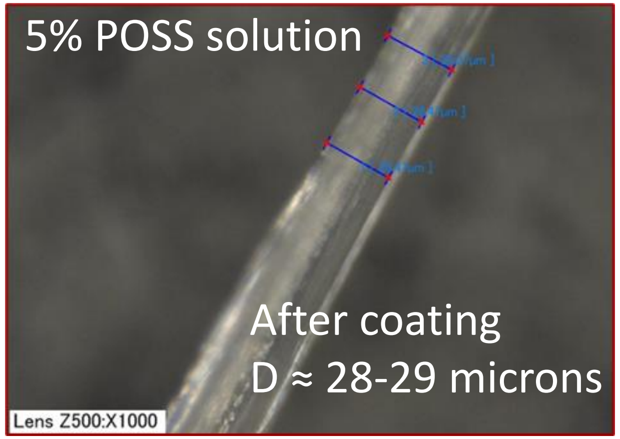


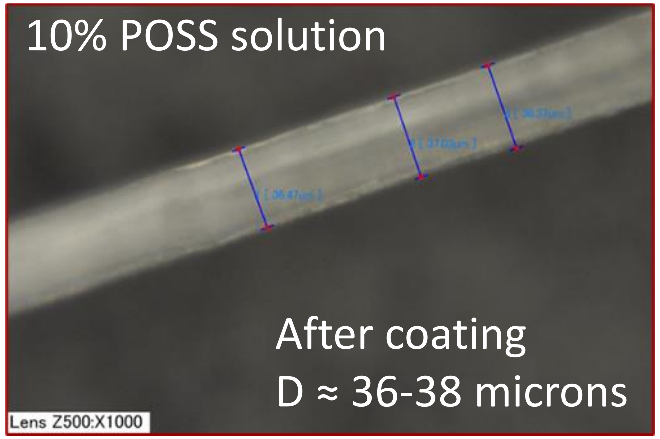
POSS Coating of HyFi Surface



Electrospraying with:
- 5% POSS solution
- 10% POSS solution





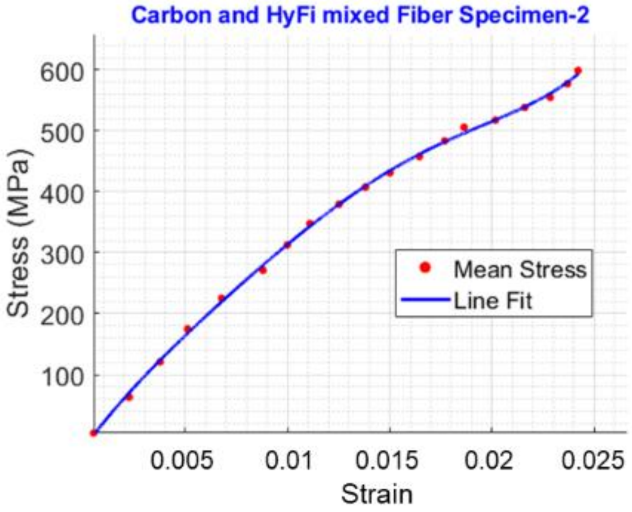


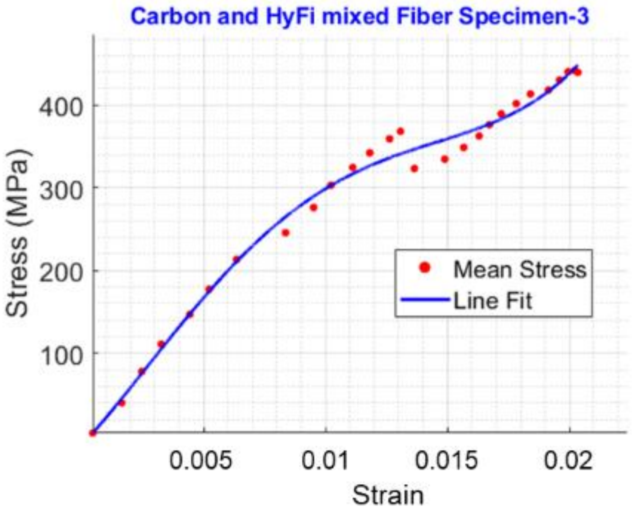
Unidirectional Long-Fiber Composite Coupon Testing

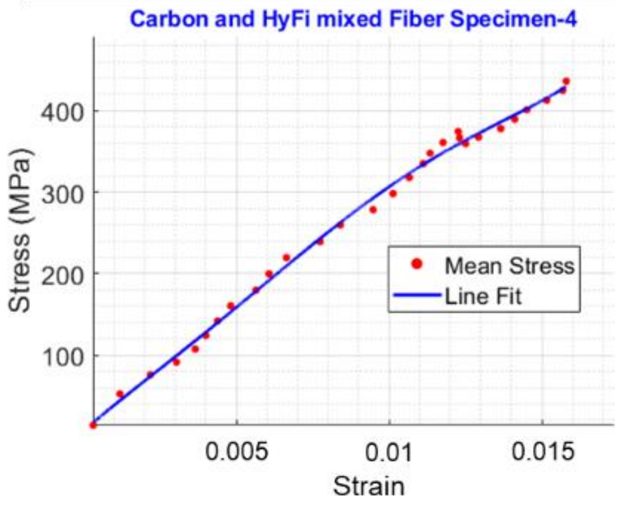
Carbon and HyFi mixed fiber specimens

Sample during tensile loading

Sample after failure







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Chopped Short-Fiber Composite Coupon Testing